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# A mathematical model of reward and executive circuitry in obsessive compulsive disorder

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## Abstract

The neuronal circuit that controls obsessive and compulsive behaviors involves a complex network of brain regions (some with known involvement in reward processing). Among these are cortical regions, the striatum and the thalamus (which compose the CSTC pathway), limbic areas such as the amygdala and the hippocampus, and well as dopamine pathways. Abnormal dynamic behavior in this brain network is a hallmark feature of patients with increased anxiety and motor activity, like the ones affected by OCD. There is currently no clear understanding of precisely what mechanisms generate these behaviors.

We attempt to investigate a collection of connectivity hypotheses of OCD by means of a computational model of the brain circuitry that governs reward and motion execution. Mathematically, we use methods from ordinary differential equations and continuous time dynamical systems. We use classical analytical methods as well as computational approaches to study phenomena in the phase plane (e.g., behavior of the system's solutions when given certain initial conditions) and in the parameter space (e.g., sensitive dependence of initial conditions).

We find that different obsessive-compulsive subtypes may correspond to different abnormalities in the network connectivity profiles. We suggest that it is combinations of parameters (connectivity strengths between regions), rather than the value of any one parameter taken independently, that provide the best basis for predicting behavior, and for understanding the heterogeneity of the illness.

## 1 Introduction

### 1.1 The obsessive-compulsive disorder and its brain dynamics

Obsessive-compulsive disorder (OCD) is a severe mental disturbance affecting around 2-3% of the US population. Its symptoms are chronic intrusive thoughts (obsessions) and/or repetitive behaviors (compulsions), which can lead to significant impairment in psychosocial functioning [1, 33]. While medication plans and behavioral therapy may benefit some patients, 20-40% of OCD patients – often those most severely affected – remain refractory to treatment [58, 4].

According to the American Psychiatric Association, obsessions are repetitive, intrusive, and distressing thoughts, ideas, images, or urges that often are experienced as meaningless, inappropriate, and irrelevant, and persist despite efforts to suppress, resist, or ignore them [1]. Compulsions are repetitive, stereotyped behaviors and/or mental acts that are used to diminish the anxiety and distress associated with the obsessions [1]. It has been noticed that obsessions and compulsions are often linked by content. For example, obsessive recurrent thoughts about erring may trigger compulsive checking of the work, and obsessive contamination concerns may lead to compulsive washing routines [37]. Although the DSM-IV criteria imply that it is possible for a person to experience compulsions without obsessions or vice versa, the vast majority of OCD patients have both obsessions and compulsions. Indeed, only 2.1% of patients with OCD report predominant obsessions, 1.7% report predominant compulsions, and more than 95% reported both obsessions and compulsions on the Yale-Brown Obsessive Compulsive Symptom Checklist [17].

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